XIII.—*On certain Arid Countries, and the Causes of their Dryness.*

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IT has been shown, in my former papers,* that there are certain areas of condensation of aqueous vapour, within and near to mountainous regions of the tropics, towards which general winds blow from parts far distant, constituting what are commonly called the tropical trade-winds of the Atlantic and Pacific Oceans. The N. and N.E. winds that blow over the continents of Europe and Asia have also been pointed out as aërial currents flowing towards partial vacua, which are produced in areas of condensation, presenting, it is contended, evidence of the origin and nature of the disturbances that produce these great movements of the atmosphere. When winds which are dry pass over the surface of the ocean they readily take up moisture, and become charged with the vapour which is subsequently condensed, creating a vacuum, and producing rain at their termini. But when a partial vacuum in the atmosphere is thus produced, heavier air presses in, and flows, as a wind, from distant parts, not only over the ocean, but also sometimes over low-lands of continents, as we have seen that it does over the lands of Asia and Europe, giving to large districts of countries particular geographical characters.

These last-named winds are, however, not the only ones which blow from certain parts, where the air is dry, to other parts where it has been made light by condensation of vapour, although they are perhaps better known to Europeans than similar winds found in other quarters. In the northern portions of America, particularly during the winter, the air generally flows from the N.—from one part that is comparatively dry and heavy to another part which has been rendered light by condensation of vapour, brought by the tropical trade-wind from the Atlantic Ocean to the Gulf of Mexico. In the winter a wind generally blows southward across Canada and the United States, producing the cold climate of these countries. Various writers have described the intense cold of northern Canada. Lewis and Clarke mention the lingering of the winter cold on the Upper Missouri, and "the northers" blow fiercely in the winter into the Gulf of Mexico. The great mass of air, therefore, that passes over this continent in the winter flows southward to the Gulf of Mexico, in the neighbourhood of which, and against elevated land, the vapour that is at the same time brought from the Tropical Atlantic is largely

* *See* 'The Atmospheric Changes that produce Rain and Wind.' Weale, Holborn.

condensed. Thus these two winds, North American and Asiatic, pass from regions where the air is cold and dry to localities where warm air brings copious supplies of vapour for condensation; and the dry winds thus brought tend to re-establish the equilibrium of atmospheric pressure which had been destroyed by the condensation.

A part only, however, of the vapour of the tropical seas passes into the Gulf of Mexico, as large portions of it turn northward, over the Atlantic as well as over the Pacific Oceans, which portions are condensed on the western coasts of Europe and America. But the air which contained the vapour does not, after that vapour has been condensed, return to the tropics over the same two oceans, as in neither of them do *north* winds prevail. The moist *south-west* winds of the Atlantic, after being deprived of a large part of their vapour by cold, return in a dry state over the low lands of the old continent; whilst the *west* winds of the northern part of the Pacific—after furnishing the rains of Western America—pass over Russian America and Behring Strait towards the Arctic Ocean, and return over the low lands of the central part of America as dry winds. Both of these land-winds are dry, because they have been deprived of much of their vapour, among mountains, by cold; and they afterwards pass from colder to warmer latitudes, which renders them more capable of taking up moisture: and they press and flow towards their termini, because there vapour has been brought from other parts by other winds, to be condensed and to create a comparative vacuum in the atmosphere.

Being in the northern hemisphere, these winds, with their peculiarities, are known to European meteorologists, but these meteorologists do not admit that *the prime disturbing cause is the condensation of vapour producing a vacuum in certain localities within the tropics*, as I have explained. In the southern hemisphere we have facts of a similar character, which are not equally well known. In that part of the world, as in the north, dry winds blow from cold to warm latitudes, giving a particular character to certain districts; and they also, as in the north, terminate in localities where a partial vacuum in the atmosphere has been created by condensation of vapour which has been brought from other parts. And thus we find that in both hemispheres cold and dry winds blow—not generally towards the equator as N.E. and S.E. winds, as is commonly assumed—but directly towards local areas of condensation of vapour, which areas are always found to be elevated lands, against which, at the same time, warm and moist winds also blow.

In the southern hemisphere there are not such broad continents as there are in the northern, yet the same flow of air over

land—rather than over water—from cool to warm latitudes, is observable in the former as in the latter. But there is ample breadth of ocean in the southern hemisphere over which a cold aërial current might pass from the Antarctic Ocean to the tropics, and thus restore the equilibrium of pressure in a disturbed atmosphere in the way indicated in the Hadleian theory of winds, if the causes of atmospheric disturbance recognised in that theory were those which are really in operation. Over the whole Southern Ocean, however, no palpable polar wind is to be found blowing to the tropics, such winds being confined to the comparatively small portions of land which exist in that hemisphere.

Four separate winds in the southern hemisphere may be traced, blowing from the s., in a way that makes them correspond with the dry northern winds in the northern hemisphere, giving a particular character to the countries over which they pass, namely, two in America, one in Africa, and one in Australia. And to these southern winds and their places of termination we may now direct our attention, in order to trace the prime causes of the disturbances of the atmosphere in this part of the world that produce such marked effects over extensive countries.

The first of these which may be noticed is the wind that blows along the low land of the western coast of South America. It is first found about Valparaiso, say in lat. 33°, blowing moderately, but it increases in strength as it proceeds towards the equator, passing over Chile and Lower Peru, until it reaches the province of Guayaquil, a place which may be described as being in the most southern part of a very rainy district, included between 5° s. and 8° of N. lat., into which much vapour is brought from the heated surface of the Bay of Panama, extending westward into the Pacific Ocean and the Mexican and Californian Seas. Now, if an atmospheric current is made to flow from the polar to the equatorial regions, in the way alleged in the Hadleian theory of winds, why have we not a S.E. wind blowing over the whole Southern Ocean between America and New Zealand, instead of the present limited Peruvian wind over a narrow strip of land? In this wide range of open sea, a W. wind of a decided character blows across the part s. of lat. 38°, and nearer to the equator a broad strip of calm occurs, until the eastern trade wind of the southern Pacific is reached; but over the whole of this extensive ocean no such S.E. wind is found blowing from the polar towards the equatorial regions, as would certainly blow there if the Hadleian theory were true. The south wind of Peru does not extend far over the sea, but clings to the land, passing along the western slope of the Andes until it reaches the region of condensation that has been named about the Bay of Panama. And this it does, although on the western side of the Pacific, among the lofty islands of Austral-

asia and the Asiatic Archipelago, such condensation of vapour takes place as produces E. winds across both the South and North Pacific Oceans. The south Peruvian wind is at last to some extent absorbed by the great eastern trade wind, but this takes place within the tropics, near to the American coast, whilst no palpable S. or S.E. wind blows to the tropic in the open space between America and New Zealand.

Of the Peruvian line of coast Mr. Darwin thus writes,—"At Arauco, near Quiapa, the country never suffers drought, the climate being a happy mean between the dry parching heat of northern Chile or Peru, and the continued wet wind and chilliness of Chiloé. June 3. Northern Chile.—The whole country, from the coast to the Cordillera, is desert and uninhabited, from Yerba Buena to Carizal. Port of Iquique, lat. 20.—A slight shower of rain falls only once in very many years, and the whole country is utterly desert"—p. 427. Captain FitzRoy says, "the city of Coquimbo is called '*La Serena*.' In settled weather a fresh southerly wind springs up, a little before noon, and blows till about sunset. The usual strength of the southerly sea-breeze, as it is called, though it blows along the land from the s., is such that a good ship would carry double reefed top-sails. The coast of Peru is free from storms, the wind blows moderately along the land, or from it, and there is little or no rain"—p. 483. "The country is arid"—p. 481. "Point Jara, Lat. 23 s.—Neither water nor timber is to be had within 25 leagues of this place"—p. 209. Such is this line of country; and the dry wind continues to blow, giving the country, over which it passes, a desert character, until it approaches rainy Guayaquil, situated in 5° of s. lat.

The second American dry S. wind, in this hemisphere, is found on the eastern side of the Cordillera of the Andes: it therefore blows in a direction nearly parallel with that on the western coast, though not in the same latitudes. It commences its course not far from the Straits of Magellan, and passes over eastern Patagonia and the Pampas of Buenos Ayres, approaching the great region of condensation of vapour that exists on the eastern side of the Andes, and which furnishes the immense volumes of water that flow down the great La Plata and Amazon rivers. This extensive line of flat country, from the Straits of Magellan to the region of condensation named, is dry—like Siberia and Bokhara, in the northern hemisphere—indicating what is known to be the fact, that "the Pampero," or Pampas wind, is itself dry; and it blows towards a region where the atmosphere must be made light by the large amount of vapour coming from the tropical Atlantic, that is known to be there condensed, forming a partial vacuum, into which the cool and dry air passes from the line of country that

has been pointed out. The dry air itself does not take sufficient vapour to produce a considerable vacuum at the place of its termination, nor does much rain fall, excepting among the Andes, to the south of say the 25th degree of latitude, in the countries over which the dry air passes. The vacuum that gives birth to this southern wind is, therefore, evidently produced by condensation of vapour, which is brought mostly up the broad valley of the Amazon from the tropical Atlantic Ocean; and that condensation, by producing an atmospheric vacuum, must be considered the prime disturber of the aërial equilibrium in this part of the world, which the influx of air from the south tends to restore. We thus see that in South America there are two south winds blowing along opposite sides of a range of mountains, towards two particular localities, where copious condensation is known to be taking place, whilst winds do not generally blow from the polar region, over the southern Pacific, towards the line of the equator.

Of the dry country north of the Straits of Magellan, Darwin says, "On the eastern side of the Cordillera, from lat. 38° to Tierra del Fuego, where a blue sky and fine climate prevail, the atmosphere has been drained of its moisture, and the arid plains of Patagonia support a scanty vegetation. The country near the mouth of the river (Rio Negro) is wretched in the extreme; water is extremely scarce, and, where found, is invariably brackish.—p. 73. The river Colorado, nearly 80 m. distant north, is separated by a dry desert. From the dryness of the climate, a man may walk for days together over these plains, without finding a single drop of water." And Captain FitzRoy states, that "From Cape Corrientes to Bahia Blanca is a long and dreary line of coast, without a river whose mouth is not fordable. And in the interior, but verging on the shore, is a desert tract, called by the Indians 'the country of the devil.' The most serious objection to this country is the want of rain. Generally a bright sunny day is succeeded by a cloudless and extremely clear night. Two or three years sometimes pass without more than a slight shower."—p. 105.

The third locality in this hemisphere, in which a dry region may be found, is Southern Africa; but we are not in possession of the same amount of information respecting this part that we have of South America, which fortunately has been visited by intelligent travellers. A large portion of South Africa is absolutely unknown to us, and the known parts have been little visited by scientific observers; we are consequently without much information of the hygrometrical state of the atmosphere in this country. Even the amount of rain that falls annually is unknown beyond the Cape district, and the immediate neighbourhood of a part of the east coast. We have, therefore, to infer the state of the atmosphere mainly from the water discharged by rivers. On neither the

eastern nor the western coast, from the Cape to about the sixth degree of latitude, are there such discharges of water as are found in America and Asia. It appears that the country does not rise to a sufficient elevation to produce copious condensation of vapour and consequent heavy rain, and therefore little water is borne to the sea by rivers. The dry central part of South Africa extends from a few degrees south of the equator to, say the 30th degree of latitude, and it is of an average breadth of, say 15 degrees of longitude, extending from about the 15th to the 30th degree of east longitude; yet in the whole of this large space no considerable river is found. The Orange and the Great Fish rivers occasionally send water freely to the ocean, and there are others on the eastern coast, but no large volume of water descends in any of them, nor are they navigable far from the sea. Those who have attempted to explore the interior have found the country generally dry, so much so, indeed, as to leave the explorers often greatly distressed through a want of water while passing from one small stream to another. There is not here that entire absence of water over a large area that is found in the great Sahara to the north of the Equator; nor does the country appear to be quite so destitute of that important article as is a large part of eastern Patagonia; but yet it may justly be called a dry desert country. The deficiency of water renders it almost inaccessible to explorers, and that deficiency is evidently the cause of such a small number of human inhabitants being found in it by travellers.

Captain W. Harris, in his Wild Sports of Africa, thus speaks of this geographical locality when in lat. 29° on the plains of the Vaal river. "In common with other countries remote from the sea-coast this portion of the continent receives its rain in thunder-showers during the summer months; and there being none during the rest of the year, the climate, notwithstanding frequent nocturnal dews, is characterized by extreme aridity. The sun shines with matchless splendour through a sky of delicate blue, which is rarely visited by a cloud."

Now, there can be little doubt that the cause of this country being in such a condition as that described is the same as that which has been traced in South America. The land in general is comparatively low, as it is in eastern Patagonia; but towards the north it becomes more elevated, and, as the equator is approached, mountains appear, some of which are so high as to be covered with snow. The Rev. Mr. Rebmann, during a journey in November, 1848, observed that these mountains are within 4° s. of the equator. "There are (he says) two summits rising to the limit of snow out of the common mountain mass. The eastern is the lower, and terminates in several peaks, the snow on which varies with the season. The western summit is the proper perpetual

snow mountain; it rises above its neighbour, and is formed like an immense dome. It is 10 or 12 m. distant from the eastern summit, the intervening space presenting a saddle."

This is about the locality which has been long noted on some maps as having perpetual rain; and towards this part winds blow from different quarters, some of them no doubt bringing the vapour which produces the rain. There does not seem to be any strong aërial current coming from the Indian Ocean, which lies to the east, and the coast of Zanguibar is known to be dry; but from the Gulf of Guinea and the Atlantic, a wind is stated to be always blowing, and generally with considerable strength. The tropical air in this gulf is of high temperature and very humid, being nearly saturated with vapour; and from the Atlantic Ocean, on both sides of the equator, this air rushes across the gulf towards the mountain region of perpetual rain, supplying the material for producing the rain and creating a partial vacuum in the atmosphere. But the mass of air which blows over the comparatively low country of Southern Africa from the neighbourhood of the Cape of Good Hope passes towards these mountains from cooler to warmer latitudes, and therefore will be dry in its passage. This dry wind is not so uniform, nor always of such strength, as that which is found in some other parts similarly circumstanced, as, no doubt, it is more or less disturbed in its passage by hills and ridges of land, but it appears generally to blow from the south. Now, air passing from 30° of s. lat. towards the equator would, at the level of the sea, be disposed to take up rather than to deposit moisture; to receive vapour through evaporation, rather than to furnish it for condensation; and as the country does not rise to any great height until the equator is approached, this mass of air passes over the continent of Southern Africa generally as a dry wind. Here, then, we see why South Africa is a desert country. Like Eastern Patagonia and the waterless desert of Peru, the winds that blow over it go from a cool latitude to a warm one; but they do this evidently because in the warm latitude a comparative vacuum is made in the atmosphere by an almost constant condensation of vapour which has come from another locality to a mountainous region.

It has been stated that little water is discharged by rivers from the southern part of this continent; but such a statement does not apply to the mountainous regions near the equator, and extending from it to the western coast, as a large body of water passes down the great river Zaire or Congo, as well as down other rivers which run westward from the mountains and enter the Atlantic to the south of the equator. We therefore have good evidence that in the central part of Africa there exists a region of condensation of aqueous vapour, which vapour is brought principally from the

Gulf of Guinea, and condensed among mountains, producing a vacuum, towards which the air from more southern parts presses and flows as a southern wind. And being carried into the vacuum, and ascending to a sufficient height, its own portion of vapour is cooled and condensed, increasing the vacuum, and augmenting the rain-fall in the area. This course being continued and perpetuated makes Southern Africa the dry and barren country that it is, and so difficult to be explored by travellers.

The interior of Australia is little known, and therefore somewhat difficult to deal with. The few inhabitants who have gone from Europe to that country are generally settled on its coasts, or on the banks of rivers, the greater part of the interior being left in possession of the uncivilised natives who wander over its vast and almost barren solitudes. Various attempts have been made to discover the state of the interior parts, but they have ended in failure, rather from a want of the means of subsistence than from the hostility of the natives. The south-eastern are the parts principally occupied by European settlers, those parts being supplied with water; but, in proceeding northward, interminable plains are found which are little visited by rain. In its present state this part of the world does not yield subsistence to civilised man; it is, therefore, very difficult to explore, and undesirable to occupy. Such being the state in which this country is found, we are obliged to rely on facts which have come to our knowledge that have an analogy with others in better known countries. We have seen, in the parts already treated of, two features presented to our view that are common to them all, they being all traversed by dry air, and that air passing to localities of great condensation of vapour. And as Australia is found to be dry, like South Africa, Eastern Patagonia, and Western Peru, we naturally ask whether the cause which has produced the dry and barren state of these countries is to be found in active operation in Australia? In some of the more southern parts this is certainly not the case, as the falls of rain in them are equal to what are found in the better parts of Europe. And there are some extensive rivers, the Murray being navigable for hundreds of miles. But a very large portion of this country, say between the latitudes of 20° and 30° s., is, as far as known, without an adequate supply of water. Like the worst parts of South Africa, these extensive regions are exposed to a scorching sun unscreened by clouds, and scantily supplied with rain.

Sir Thomas Mitchell, in his Travels in Australia, says of this country,—"An almost perpetual sunshine prevailed; dry cirro-cumulous clouds indeed sometimes arose, but no point of the earth's surface was of sufficient height to attract them. There seemed neither on the earth nor in the air sufficient humidity to

support a cloud. Dew was very uncommon. The hot winds of the Bogan brought no antidote as in Sydney. On the Bogan (in lat. 31°) the air was oppressively hot during the night" (vol. i. p. 31). Many other persons who have written of this part of the world describe it in the same manner.

Now north of this country, among the islands of the East Indian Archipelago, there exists an area of condensation of aqueous vapour probably equal in magnitude to any other on the surface of the earth. It has been shown in a former work that different currents of air saturated with vapour flow towards and terminate about these islands. These aërial currents come from the Arabian Sea on the one side, and from the China Sea on the other; from the Indian Ocean during the north-west as well as the south-west monsoons; and from the wide expanse of the Pacific Ocean, on both sides of the equator, almost without intermission. These currents of humid air produce heavy rains on and near to the lofty islands, which must create considerable atmospheric vacua into which the aërial currents rush and create ascending vortices, the process being constantly renewed and perpetuated. Presuming that in the interior of Australia there are no elevated lands up which moist air is made to ascend and condense its vapour, and thus determine a flow of air towards such lands, the atmosphere over this country would be impelled by its own weight towards the vacua over the islands, into which it would enter and ascend, leaving other air to follow in the same course, and constitute a general wind blowing from the south across the whole country. This is evidently what takes place, and it accounts for the dry wind that passes over Central Australia. As already pointed out, any wind passing from S. to N. in the southern hemisphere, moves from a cooler to a warmer latitude, and must consequently have its temperature raised by the greater power of the sun, thus making it a drier wind. And such a wind passing over land of only moderate elevation would not readily furnish rain; but, on the contrary, would be disposed to take up water by evaporation from any wet surface, and thus soon dry up any small streams which might descend from such hills as had produced a little rain. Hills, and even mountains, are said to exist on the north-eastern side of the country; and there may be some in the interior on which moderate rains fall, relieving the general state of dryness; but these, from all the accounts given, seem insufficient to counteract the great effect produced by condensation of vapour over the large and lofty islands of the Archipelago, which leaves the central plains of Australia dry, scorched, and barren, like the Great Sahara of Northern Africa.

It may, however, be observed, that at the commencement of the dry lines of country in the southern hemisphere, that have

been described, rainy districts exist. The Cape of Good Hope has a considerable supply of rain; Van Diemen's Land is a wet country; and Tierra del Fuego and Western Patagonia have drenching rains that hardly ever cease falling, summer or winter. The vapour which is known to be abundant over the wide extent of the Southern Ocean is therefore to a certain extent condensed in these mountainous countries, and ascending atmospheric currents, more or less strong, must be formed over them. The air in these localities may, therefore, be deprived of some of its moisture before it passes towards the tropics; and it is very likely that this dried air descends and flows over the arid lines of country that terminate in the tropical localities of great condensation of vapour. Were there no elevated lands at the three last-named places, the air to the north of them would probably have more vapour than it now has, and might resemble that which flows over the continent of North America, which has a certain degree of dryness, because it passes from a cool to a warm latitude, rather than from having had its vapour condensed by ascension of mountains at its northern extremity. The extreme southern rainy localities may, therefore, make the winds which are passing from them drier than they otherwise would be; but it is the large amount of condensation of vapour, and the consequent vacuum at the terminus, that create the dry aërial current in each locality.

The four southern countries that have been described have, then, all the same geographical features of climate and character; and these features are evidently determined by the particular winds which blow over them. And the general characters are the same as those of other countries formerly examined by me in other papers, that is to say the deserts of Bokhara, Persia, and Arabia, and the great desert of Northern Africa. In all these parts, dry winds blow towards localities, known to be areas of condensation of vapour, and therefore where comparative atmospheric vacua must be created; and no cause, but these vacua, seems to be capable of producing the winds. A general flow of the atmosphere in the lower regions, from cold to warm latitudes, would not create local winds, blowing to particular points or areas, but would cause the air to pass over the extensive low level of the ocean towards the equator in a uniform manner and direction.

In July, 1853, at a meeting of an American Association for the Advancement of Science, a paper was presented by Mr. L. Blodget, in which, among other things, it was stated that, in the western part of Texas, "*a monsoon* blows from May to November, day and night, for months together, over the whole district bounded by the Rio Grande and the San Pedro and Picos on the S.W., and merging gradually in the low plain of Texas on the E." This wind is claimed as "a true desert monsoon, and analogous

to the desert winds of Africa and Asia." And it is asserted to be "a non-precipitating wind, increasing in temperature and rarefaction, and exhausting itself in a rainless district beyond which it does not extend." This part was previously almost unknown to European meteorologists: the facts are therefore interesting. The locality described appears in the summer to have the character of a dry desert, and to be similar to the lines of country in the S. that have been traced. But Mr. Blodget says that the dry winds exhaust themselves *in* a rainless district! Is this only *a belief*, such as is so often entertained, and therefore announced as a fact? or is it an *ascertained* fact? The wind is described as blowing in the summer season from the S.E., and of course from the Gulf of Mexico, over low land, towards the high Rocky Mountains, among which all the great rivers extending from the Red River to the Missouri take their rise. Now these rivers are known to be supplied with water to such an extent as to prove that heavy rains must fall about their sources, and winds blow up the valley of the Mississippi constantly during the summer, bearing, as may be presumed, the vapour which is condensed among the Rocky Mountains. The probability therefore is, that this south-east monsoon, which passes *over* a rainless district, blows to the area of condensation, at the sources of the rivers, among the mountains. Further accounts may show whether this locality forms an exception to many others that have common characters, or that Mr. Blodget had observed only a part of the phenomena open to his examination, when he supposed he had seen the whole. When a dry wind blows into a vacuum among mountains, produced by vapour brought from another quarter, the wind may enter the vacuum at a considerable elevation, and in the latter portion of its course may not be palpable near the surface of the earth; this seems to be the state of things between the desert of Scinde and the Himalayan mountains. But if heavy rain falls in a locality towards which a dry wind blows, we may safely infer that it blows towards a rain-made atmospheric vacuum. Should the part described by Mr. Blodget prove to be a district made rainless in summer, by condensation in the country to the north of it, it will prove a striking instance of the power of vapour to cause a wind to blow towards the place where its condensation is occurring. The vacuum about the sources of the Missouri would be proved to be sufficient to draw air even from the Mexican gulf, in opposition to the powerful influences that exist in other parts around that gulf, and also to make the air pass northward over the rainless district described.

It is generally asserted in meteorological works, in accordance with the Hadleian theory of winds, that in the northern hemisphere, the polar aërial current returns to the tropics as a north-

east wind, until within the tropics it becomes an east wind. But this is not correct, even as far as respects the land in Asia, a part long known, as over Siberia and Bokhara it is north, in Persia and Arabia it is a general north-west wind, and blows as such in the winter over the Arabian Sea and the Northern Indian Ocean. Up the Valley of the Nile the perennial wind blows from the north. Over the immense extent of the flat Sahara the predominant direction of the movement of the atmosphere, fitful and irregular as it is, is towards the Rainy Mountains near the equator; and this direction is changed in a decided manner only at certain times when the "Harmattan" prevails; this temporary wind being now known to be produced by tornadoes in the Equatorial Atlantic. What is called the "eastern trade wind" in the Northern Atlantic, as has been shown, is caused by condensation of vapour against the Cordillera of the Andes.

In like manner, the wind that passes over the middle of the continent of North America in the winter, the time when the polar winds are supposed to be the strongest, blows from the north, but is more inclined to become a western than an eastern wind. Where this wind is first found, near the mouth of Mackenzie River, the most western part is in about the 130th degree of west longitude, whilst at the southern terminus in the Bay of Mexico and the West Indies, the most western portion does not go beyond the 100th degree of west longitude. And it often blows over the United States to the eastern coast, as a north-west wind, making that country very cold in the winter. There is certainly a barrier to this wind in the Rocky and Mexican Mountains, along the eastern side of which it blows, as a "norther," into the Gulf of Mexico; but this does not alter the fact of the wind being generally a north-west, rather than a north-east wind, blowing from the polar to the tropical regions. And what is the state of the atmosphere on the western side of this barrier? Is a north-*east* wind found there? No—the whole mass of air is in motion across the Northern Pacific, not from the north-east, the direction in which theory has represented the polar winds as blowing in the northern hemisphere, but directly from the west. A strong western wind blows in the Northern Pacific, up to about 60° of latitude, bringing heavy rain to the whole American coast.

Whilst no north-east wind blows over the Northern Pacific, it is well known that westerly winds generally prevail in the northern part of the Atlantic, leaving the aërial polar currents to pass towards the tropics over land alone, as in fact they generally do, in the way already described: and these various winds show us, pretty clearly, what are the great movements of the atmosphere in the northern hemisphere. In southern parts, beyond the tropics, no decided south-east wind is found. With small exceptions, the whole of this portion of the surface of the globe, south of 38° of

latitude, is ocean; but in no part have we a south-east polar wind, such as, in the common theory, is said to exist. In this hemisphere, outside of the tropics, there is not much elevated land to produce condensation of the vapour that is so abundant over the Southern Ocean, and therefore masses of air are not so extensively transferred from one latitude to another, as in the northern hemisphere. Air must nevertheless be cooled in the southern polar regions, but it passes towards the tropics over land, and not over the ocean. The tropical trade winds of the Atlantic and Pacific Oceans are then those which alone remain to countenance the Hadleian theory, as they, no doubt, originally suggested it. But the causes of these winds have been clearly shown to be condensation of vapour against the elevated ridges of the tropical Andes, and the lofty islands of the East Indian Archipelago. And it has also been proved that mountains within the tropics produce west winds, as in the Gulf of Guinea, and on the western side of the Eastern Archipelago; and this could not take place if the Hadleian theory were true.

In treating on the subject of particular winds, and tracing their proximate causes, considerable difficulty is experienced in distinguishing, with simplicity and clearness, those that are local and temporary, from others that are more general and comparatively permanent. Of the former it has not been proposed to treat in the present paper, but still it is desirable to observe, that over very large portions of the earth there are numerous local causes of disturbance in the atmosphere, that produce limited and temporary effects. In addition to, and apart from these, however, there are, about certain elevated lands, causes of greater and longer continued disturbances, which make them more or less permanent; and some of these have been more particularly considered in this paper. But in order to obtain a clearer view of the working of these causes, it becomes necessary to pass over numerous small and temporary disturbances, which more or less interfere with the larger and more permanent, and always force themselves on the attention of casual observers. To introduce and discuss these in detail, at the same time that we are considering the special results on the earth's surface of more important disturbances, would however produce complication, render the subject more tedious and difficult to understand, and involve it in an obscurity which does not belong to it. The general laws, or principles, which govern the changes that take place in our atmosphere, are not very obscure or complicated; though, perhaps, they may appear to be so, from only occasional observations of the phenomena, and from the way in which the subject is generally treated. Yet, in this respect, meteorology does not materially differ from other sciences, some of which were formerly equally obscure. Chemistry in the hands of the alchemists was as chaotic and incomprehensible as

meteorology is at present. And to ancient astronomers, not having the clue to assist them, which a knowledge of the laws of gravity affords, the heavenly bodies appeared to dance through the heavens in complicated and involved figures that defied analysis. But the laws of combination in definite proportions in the one case, and of the mutual attraction of ponderable bodies in the other, have furnished means of rendering that which was formerly a mass of confusion or obscurity, comparatively clear and simple. And the different laws of cooling by expansion of the constituents of the atmosphere, and those which govern heat in its chemical union with, and separation from, water, when properly understood, seem to afford equal evidence of the nature of the changes which are ever taking place in our atmosphere.

Under the operation of these laws, certain localities have great influence in producing motion in the atmosphere, and creating the general currents in it which determine its circulation. Over the ocean, evaporation is constantly taking up vapour, which by its elastic force expands and diffuses itself through the gases; and the amount of heat thus taken up, to be afterwards used in expanding the gases in particular localities, is enormous. Through a difference in the laws of cooling, by expansion, of vapour and gases, this heat would, in all parts, be given out at certain heights, when the cold of the gases condensed the vapour, and rains would fall with considerable uniformity. But as there are certain elevated lands distributed over the surface of the earth, against these the vapour is largely condensed, and towards these lands atmospheric currents flow, or winds blow, producing continuous aërial movements, and ascents in the area of condensation. The ascents cause a boiling up and overflowing of large masses of the atmosphere, in the higher regions where they diffuse themselves, and in time descend, perhaps in parts far distant, or they may press upon and put in motion other parts beneath them.

Many of these localities of condensation have been pointed out in this as well as in former papers, but they may be here brought together in an order relating to their importance. The first that may be named is found on the eastern side of the lofty Andes, where the rivers La Plata, Amazon, and Orinoco have their sources. The second is in and about the Himalaya Mountains, from which all the great rivers of Southern Asia take their rise,—the Indus, Ganges, and Brahmaputra in Hindostan; the Hoang-ho, and the Yang-tse-kiang-keou, in China; and many other large streams. The great Asiatic Archipelago is the third locality, though there are no large rivers there to mark the amount of condensation. The tropical African Mountains may be next named, from which flow the Nile to the north, and the Congo to the west. The Rocky Mountains of North America, and the mountains of Chile, Western Patagonia, and Tierra del Fuego,

come next in order, as areas of condensation, to be followed by the Alps and other mountain chains of central Europe, and the Scandinavian and British mountains. Over all these mountainous countries aqueous vapour is largely condensed, giving particular characters to the respective parts; and the atmosphere is made to boil up and overflow at each place in proportion to the amount of vapour brought for condensation, and the height to which the vertical current ascends. The air discharged above, in due time comes down to the surface, and thus a general circulation of the atmosphere is established.

Direct heating, by the sun, of the surface of the globe, and consequently of the air that rests upon it, would, there is no doubt, as stated in the Hadleian theory of winds, produce to a small extent movement of the atmosphere, if it were not moved by a more powerful force; but that heating would take place gradually from one latitude to another, and by insensible gradations; the circulation of air therefore which would take place from this cause alone would be slow, regular, and feeble. When dry air, in consequence of being heated by the direct rays of the sun, now ascends in the atmosphere, it is soon cooled by expansion; and as it takes no supply of latent heat with it, to be given out when cooled, it soon acquires the temperature due to the elevation, and little disturbance is produced. As explained formerly, there is no evidence that dry air ascends over hot plains to any considerable height, nor that cool air comes in quantities to such plains, as a fresh supply to be successively heated and raised. It is not denied that any even the slightest local heating will expand air, when it will be pressed up by adjoining heavier air, in proportion to the expansion, nor that heated tropical air is to some small extent forced upwards by cool polar air. This is admitted to be true both in theory and in fact; but it is contended that it must be a slight and mild operation, and among the violent disturbances which often take place in our atmosphere can scarcely be traced.

Over the Caribbean Sea clouds have been observed in the higher regions, moving in a direction opposite to that of the wind below, and these observations have been often quoted as evidence in favour of the Hadleian theory. But these appear to be only some instances of the expansion and flow of air from very rainy localities, where it has been made to boil up by successive condensation of ascending vapour. The precise courses of upper currents are not known, but there is reason to presume that they generally flow towards the parts where the lower currents are found to commence. When clouds are seen to pass over the Caribbean Sea towards the E., whilst a wind is blowing below towards the W., it may be presumed that the upper current is passing towards that part of the ocean where the N.E. trade wind is first found as a dry wind, which is over the Atlantic at some distance from the Canary

Islands. There does not appear to be any palpable flow of air near the surface to feed this trade wind at its commencement, and therefore it may be presumed to be fed, at least partially, by descending air, which had been previously deprived of its moisture in higher regions. Such descended air soon flows over the surface towards an area of condensation, and if this should involve passing over cooler towards warmer latitudes, as the air does over the countries treated of in this paper, the parts will partake of a desert character, and might be marked as such on our maps in connection with the aërial currents, presenting a more satisfactory representation of the greatly varied surface of the globe than is to be found at present.

It is desirable that travellers exploring a country which is but little known should particularly observe certain natural phenomena connected with the atmosphere. Wind generally arrests attention to some extent, but there is not much care bestowed in describing the different kinds of winds that are met with. It is important to ascertain as far as possible the general direction in which the mass of air is moving, and whether the wind is feeble, moderate, or strong. If it should be slight and continuous, it may be presumed that the disturbing cause is operating at a considerable distance; whereas, if it is strong, and also fitful, the probability is that the cause is near. The general wind is, however, frequently broken in upon by local movements of the atmosphere, and the direction, strength, and duration of these movements should be estimated and noted, in order to furnish the means of judging respecting the locality of the disturbance and its character there. A thermometer is generally taken by all travellers, and it would be easy to have a wet bulb attached to the same frame with the dry bulb thermometer. A registration of the former with the latter, would indicate the hygrometrical state of the air as well as the temperature. A record of these instruments at sunrise, and at the hottest period of the day, say 1 or 2 P.M., would show the local changes of vapour as well as of temperature, would materially add to our geographical knowledge, and might enable us to account for peculiarities in the conditions of countries, as well as to judge of others that have not been explored. Had such information been furnished by those who have partially succeeded in penetrating the interior of Australia, it might materially assist future explorers both in determining the direction in which they should proceed and the probable kind of country they should find. The atmosphere generally is in motion over the country, and more or less indicates its condition: the atmospheric peculiarities and changes should therefore be carefully noted and recorded.